Crew fatigue research focusing on development and use of effective countermeasures

Studies of pilot fatigue and alertness have moved out of the laboratory and into the real world. The emphasis today is on applying the scientific findings to the operating environment.

NASA AMES RESEARCH CENTER
(UNITED STATES)

AROUND-THE-CLOCK aviation operations pose unique challenges. Physiological requirements related to sleep, the internal circadian clock and human fatigue are critical factors that are known to affect safety, performance and productivity. Understanding flight crews' capabilities and limitations is important to addressing these issues as global demand for aviation continues to increase.

The U.S. National Aeronautics and Space Administration (NASA) Ames Research Center initiated a programme in 1980 to examine the role of fatigue in flight operations. The programme was designed to determine the extent of fatigue, sleep loss, and circadian disruption in flight operations and how fatigue affected crew performance. It was also designed to develop strategies to maximize performance and alertness during flight operations.

The first 10 years of the NASA programme examined fatigue during regular flight operations. A series of field studies was conducted to evaluate fatigue, sleep loss and circadian disruption in short-haul, long-haul, overnight cargo and North Sea helicopter flight operations. These studies yielded a critical foundation for understanding the role of human fatigue in diverse environments.

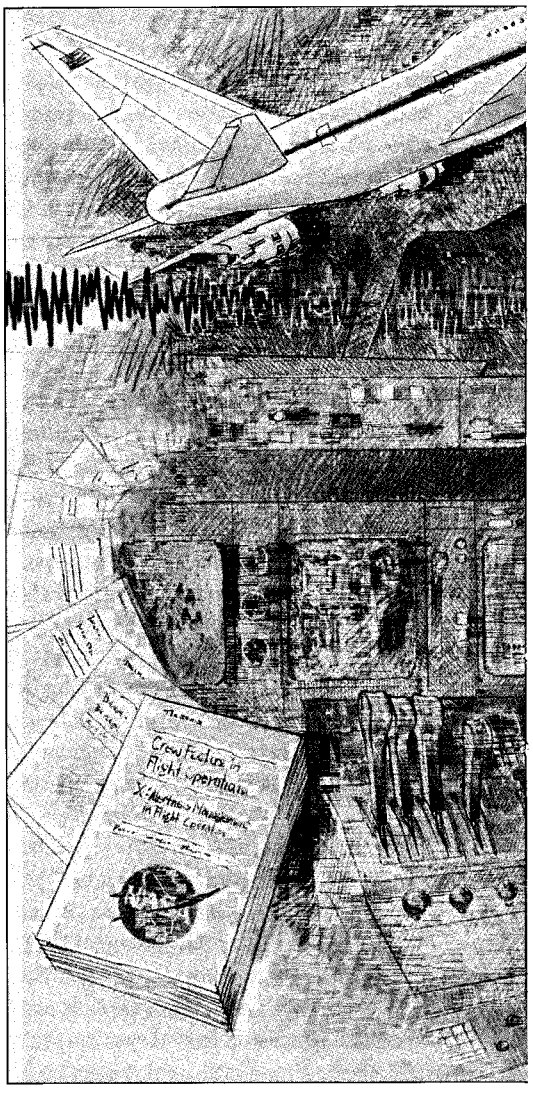
The science of sleep has been a research and medical focus for more than 40 years, but these NASA studies and activities by other laboratories in the United States (e.g. Walter Reed Army Institute of Research and Armstrong Aeromedical Research Laboratory) and around the world (e.g. DLR in Germany, the former Institute of Aviation Medicine in the United Kingdom, and the Karolinska Institute in Sweden) have moved out of the laboratory and into the real world.

In 1991, the focus of the NASA fatigue and jet lag programme shifted to fatigue countermeasures and added a fourth objective: translating the scientific findings into operational use. For the past six years this programme has addressed the complex issue of human fatigue through five major activities: research; development of equipment; education; collaboration with the U.S. National Transportation Safety Board (NTSB); and support for policy initiatives. A summary of each of these areas of activity follows.

Fatigue research. A NASA study of planned cockpit rest, in collaboration with the U.S. Federal Aviation Administration (FAA), exemplified the transition from exploratory field studies to evaluation during regularly scheduled flights. The results demonstrated that a planned 40-minute rest significantly improved performance and physiological alertness on long-haul flights. This was the first NASA study to incorporate flight crew performance measures and continuous collection of brain and eye movement activity to determine sleep/wake state and alertness. (For a report on this study, see "Cockpit Napping," October 1990.) The FAA is reviewing an advisory circular that would implement planned cockpit rest and a number of international carriers already have instituted policies and procedures to use this effective fatigue countermeasure.

Two projects have examined augmented long-haul flight operations, including the quantity and quality of on-board sleep using a crew rest area. In the first, three U.S. airlines participated in a survey to examine factors that promoted or interfered with sleep. Results from more than 1,400 crew members performing international flights indicated that although some sleeping difficulties were experienced, the crews nevertheless obtained a reasonable amount and quality of sleep using on-board bunks. This sleep was associated with improved performance and alertness. Factors were identified that could be the basis for strategies to promote optimal sleep. The survey provided initial data for a field study of these issues during actual flight operations.

The second project was a field study of physiological, performance, behaviourial, environmental, and self-report measures to examine sleep quantity and quality in augmented long-haul flights with on-board



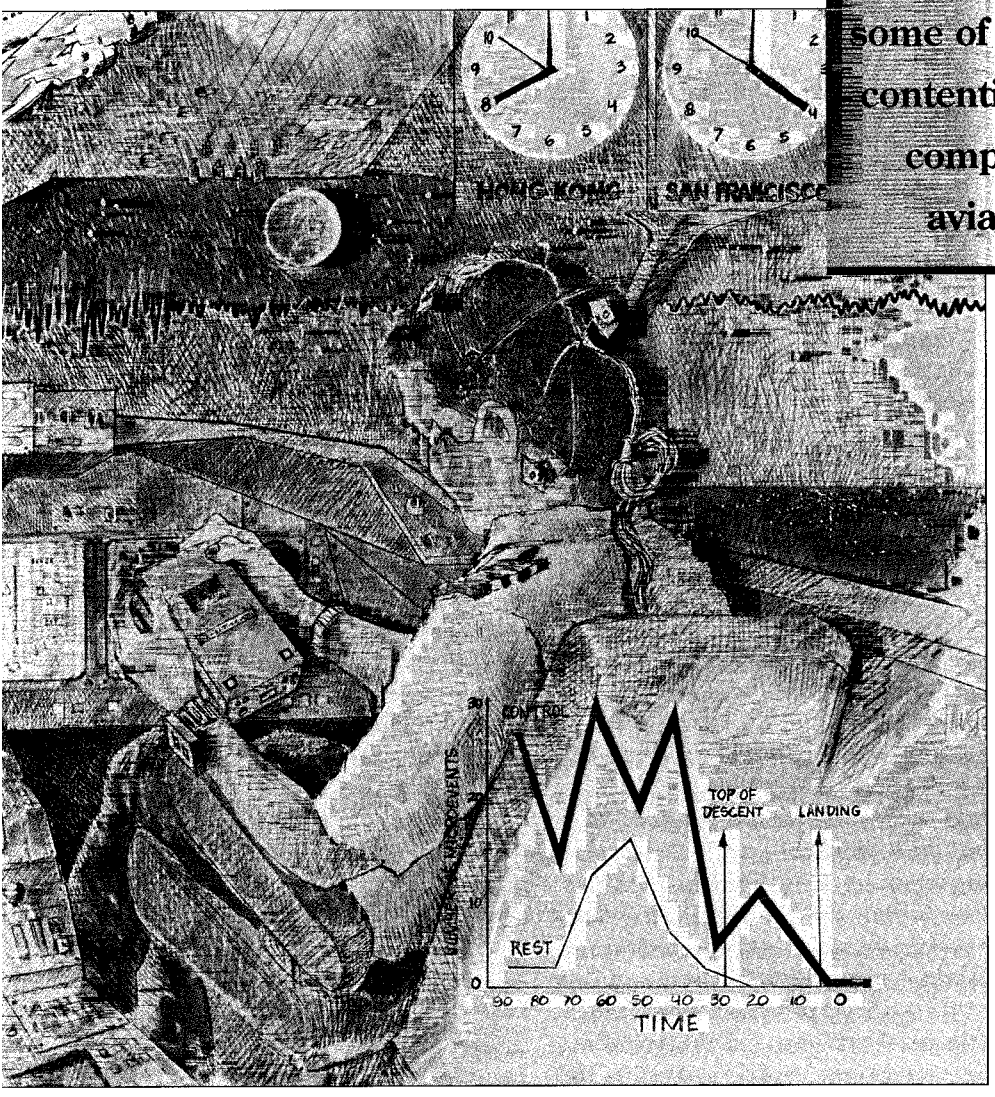
bunks. Data collected from two airlines involved in different types of international operations and one corporate operator confirmed that crews acquired a good amount and quality of sleep. Additional analysis is under way to determine the effectiveness of this regimen.

Two other surveys examined known fatigue factors in operating environments not previously examined by NASA. The first involved more than 1,400 responses from 26 regional carriers of all sizes, based in the United States. The survey included questions about duty days, flight times, collateral workload activities, weather and mechanical delays, rest opportunities, and other fatigue-related factors. This is intended to document operators' self-reported perceptions of these factors. Analysis is in progress and will result in a NASA technical memorandum.

The second survey was conducted to examine fatigue factors in corporate aviation. In collaboration with the Flight Safety Foundation (FSF) and the National Business Aircraft Association (NBAA), almost 1,500 surveys were collected from NBAA members. A significant number of respondents identified fatigue as a serious concern. Several findings demonstrated where these issues could be addressed, for example, by consistent and comprehensive flight and duty guidelines and through educational programmes.

There have been several opportunities to examine fatigue-related issues in unique operational environments. One project examined the effects of shift work in the Missions Operations Directorate which supports NASA space shuttle flight operations. The issues examined were similar to other aspects of flight operations, such as maintenance and air traffic control. Another project collected fatigue-related data during a record-breaking around-the-world helicopter trip by two pilots in 1996. This type of operational challenge provided a unique chance to obtain performance and sleep/wake schedule information.

Duty and rest scheduling issues are perhaps some of the most contentious and complex in aviation.



Laboratory-based research allows detailed examination of fatigue-related factors which cannot be adequately controlled or measured in operational settings. Collaborative laboratory studies with academic researchers are examining the effects of prolonged and restricted sleep loss (at the University of Pennsylvania), the effects of individual differences on sleep loss (Brown University), and the effects of sleep loss compared to other performance-degrading conditions (Henry Ford Hospital).

Equipment development. The original field studies of the NASA fatigue and jet lag programme used self-report measures (e.g. background questionnaire, sleep/wake log) and one physiological measure of the internal circadian clock (viz. core body temperature). The subsequent fatigue countermeasures programme has increased and improved the number of measures collected during field studies to include background questionnaires; an electronic sleep/wake diary; self-report of sleepiness and alertness; performance; physiological measures of brain, eye, and muscle activity and oxygen saturation levels; vigilance and short-term memory performance; objective behaviourial estimates of the 24-hour sleep/wake pattern continuously over a trip pattern; and environmental variables (e.g. noise, temperature, humidity). Measures are chosen to examine the specific questions addressed in a particular study.

One innovation developed and successfully implemented was the NASA Ames interactive reporting log (AIRLOG), an electronic sleep/wake diary. Historically, a handwritten log was used to collect data which was entered into a database for analysis, sometimes taking five hours for transcription. The AIRLOG is programmed with an extensive number of questions concerning sleep, wake and duty activity. The

responses can be downloaded to a laboratory computer in about five minutes, including a preliminary analysis and summary report of variables. This information is subsequently added to a more comprehensive database for complete analysis. Operator acceptance is high. Another innovation has been the development of the airborne instrument research lab (AIRLAB), which is comprised of two carry-on bags of equipment and supplies for ambulatory measurement of up to four flight crew members. It provides NASA Ames with the critical capability to collect a wide range of measures during actual operations.

A B-747 crew member contributes to NASA Ames' fatigue research by inputting data into an interactive reporting log while reclining on a bunk in the aircraft's rest area. Attachments collect data on brain and eye movement activity as well as the oxygen saturation level.

Education activities. One of the most direct methods for translating scientific findings from research to operational use is through education and training activities. To that end, an education and training module on alertness management in flight operations was developed. It describes the physiological mechanisms underlying fatigue, some misconceptions, and fatigue countermeasures.

The module was created as a one-hour presentation that highlights interaction and addresses application questions, and is complemented by a NASA/FAA technical memorandum that includes additional resources. To transfer this information to the aviation industry, a two-day trainers' workshop is provided for interested parties. To date, 24 such workshops have been conducted with 497 participants from 230 organizations in 17 countries. Virtually all components of the industry have been represented, as have other 24-hour operational environments including other modes of transportation, health care, the petrochemical industry, nuclear energy and law enforcement. Current estimates suggest that some 75 organizations are using the educational information to reach about 125,000 flight crews and others. A railroad company recently decided to use the materials to train 45,000 employees.

NTSB collaborations. The NTSB has examined a variety of human performance factors in its many investigative and safety activities and made related recommendations. NASA Ames has provided analysis of fatigue factors to support several NTSB investigations. In the investigation of a Douglas DC-8 accident at Guantanamo Bay, Cuba, in 1993, the NASA Ames fatigue countermeasures programme provided a structured approach to examine fatigue factors and analyse fatigue-related data. Based on the results, NTSB cited fatigue as a probable cause of the accident — the first time this had been cited in a major U.S. aviation accident. NTSB recommendations were made to revise regulations for flight, duty and rest periods to include the latest scientific information and provide educational material on fatigue to flight crews.

Policy support. Diverse groups, from regulatory authorities to individual flight departments, have been interested in the policy implications and applications of the scientific findings related to fatigue in flight operations. The FAA initiated a rule-making activity to examine current regulations for flight, duty and rest times, requesting NASA input on scientific research. In response, an international scientific working group developed a NASA technical memorandum, titled *Principles and Guidelines for Duty and Rest Scheduling in Commercial Aviation*, which provides an approach to managing fatigue issues. Part of this document provides significant scientific considerations, and the guidelines offer one approach to their application. The FAA has published a notice for proposed rule-making (NPRM) on flight, duty and rest periods and cites the NASA report as one source for its proposed regulations.

Duty and rest scheduling issues are perhaps some of the most contentious and complex in aviation. The FAA provided an extended comment period for the NPRM and is currently reviewing the many comments received. The same issues are being addressed by other regulators including the European Joint Aviation Authorities (JAA), Transport Canada and the Civil Aviation Authority of New Zealand. ICAO has an opportunity to provide global leadership and guidance and to support some level of harmonization.

The FSF formed a working group to address fatigue in corporate flight operations. This group, in collaboration with the fatigue countermeasures programme, used the NASA document as a foundation for recommendations. The FSF has published its own document, *Principles and Guidelines for Duty and Rest Scheduling in Corporate/Executive Aviation*, which provides an approach and specific recommendations for addressing these issues in the corporate environment. Based on the NASA programme's education and training module, the FAA has formed a working group to develop an advisory circular on fatigue countermeasures for distribution throughout the industry.

Future directions

These activities are indicative of the significant progress made on the issue of human fatigue in flight operations. There are many other contributions by research and operational groups all over the world

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To obtain information on study results and other publications about crew fatigue, write to: Fatigue Countermeasures Program, NASA Ames Research Center, MS 262-4E Moffett Field, CA 94035-1000, United States. Requests for information may also be made by fax (415-604-2177) or via the Internet (http://olias.arc.nasa.gov/zteam).

Data-link communications

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data link, when the FANS 1 avionics package was deployed in the South Pacific oceanic region. FANS 1 is now an operational service used by the FAA, Air Services of Australia, Airways Corporation of New Zealand and the civil aviation authorities of other countries in the region. Although a full description of FANS 1 is beyond the scope of this article, civil aviation authorities participating in the FANS 1 programme are connected to the network of a service provider which ensures that all messages originating at the civil aviation authority are delivered to the aircraft using ACARS. Air traffic controllers communicate with pilots using the CPDLC application. In addition, the ADS system periodically sends aircraft position reports, based on the data from the global positioning system (GPS), to ground sites. More accurate and timely position information will facilitate overall handling of aircraft through greater flexibility. During long oceanic flights, revised flight plans could be uplinked so that aircrews can avoid significant weather including turbulence.

FANS 1 promises significant savings to airlines through reduced flying times, fuel consumption and operating expenses. Because of the huge success of the initial service, the number of airlines and the civil aviation authorities participating in FANS 1 is constantly increasing around the world.

Because of increased air travel, we can no longer assume unlimited airspace capacity. The use of data link holds the key to increased and optimal airspace use. Exciting new data link applications hold the promise of continued safe and efficient operations in an increasingly busy airspace. □

Preventing pilot fatigue

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that have made significant changes in how this issue is approached. There is more to be done. First, many activities and products cited here need to be used more extensively throughout the industry. Education about fatigue must be incorporated in all training curricula.

The NASA Ames fatigue countermeasures programme continues to pursue operationally useful activities to maintain progress in this area. It is involved in development and evaluation of other potential countermeasures such as bright light, melatonin, caffeine and exercise. Another activity is exploring how an individual airline could establish its own programme to address fatigue issues. When making scheduling or reserve decisions, information could be collected to add quantitative data to the considerations. Transfer of current information to other operational settings also is under way. For example, scheduling recommendations have been made for space shuttle operations and astronauts are beginning to collect AIRLOG data. Research also must continue to examine new operating environments and challenges and support the application of the latest scientific findings in operational use. □

Collision avoidance

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purchasing the device ranges from U.S. $9,000 to $13,000 — about one-tenth the cost of TCAS.

In any design, added complexity usually means an exponential increase in cost. By making TCAD simpler — having it provide only essential information — exponential savings in cost are realized. With TCAD, electronic assistance to help pilots avoid potentially dangerous traffic conflicts is available to operators which cannot afford to install a more expensive TCAS. □

POSTS VACANT

Economist, Forecasting and Economic Planning Section, Air Transport Bureau, Headquarters, Montreal. Ref. PC 97/05/P-4.

An advanced level post at Headquarters, Montreal. *Essential* qualifications and experience: advanced university degree, preferably with specialization in economics, econometrics, business administration or operations of transportation; at least ten years' experience in economic planning, forecasting and economic analysis of air transport operations in the areas of government, airline, airport authority or manufacturing industry, including significant international experience; ability to undertake economic research, cost/benefit studies, prepare forecasts and to survey and analyze forecasting and planning methods in civil aviation; ability to draft reports, prepare clear, concise and accurate documentation and correspondence and to amplify papers to representative bodies; familiarity with modern data processing techniques and use of personal computers; judgement, initiative, thoroughness and ability to maintain harmonious working relationships. *Desirable* qualifications and experience: knowledge of ICAO functions and Organization's experience with international meetings, seminars or symposia; basic knowledge of aircraft operations and other related aviation disciplines.

Command of one of the languages of the Organization (Arabic, Chinese, English, French, Russian, Spanish) is essential and a good working knowledge of one of the others is desirable.

This level carries a starting net base salary per annum of U.S. $48,019 (without dependents) and U.S. $51,597 (with dependents). Post adjustment on initial salary step is U.S. $8,499 (without dependents) and U.S. $9,132 (with dependents) per annum and is subject to change.

Initial appointment will be on a three-year, fixed-term basis (for an external candidate, first year is probationary). *Deadline for applications: 23 September 1997.*

CNS/ATM Implementation Officer, European Office, Paris. Ref. PC 97/06/P-4.

An advanced level post at the European Office, Paris. *Essential* qualifications and experience: university degree preferably in an aviation related discipline, or equivalent qualifications and experience in the field of air traffic management and related disciplines, including search and rescue and aeronautical information services; a minimum of ten years' experience in air navigation matters in progressively responsible positions; at least five years should have been in an international environment; substantial experience in the planning, implementation and operation of advance air traffic management systems and procedures; a sound knowledge of the ICAO communications, navigation, and surveillance/air traffic management (CNS/ATM) system and the work in progress in ICAO relating to the ICAO CNS/ATM systems implementation; familiarity with activities concerning research, development, trials and demonstrations in progress relating to ATM; a good understanding of the aeronautical telecommunications network (ATN) and its importance to the ICAO CNS/ATM systems implementation; good knowledge of information systems and hands-on experience with personal computers and contemporary software for all work functions; knowledge of ICAO functions and its organization, particularly in the EUR and NAT region and familiarity with the work of other related international organizations; proven ability to write clearly and concisely and to present articulate verbal reports; initiative, judgement, thoroughness and the ability to maintain harmonious working relationships in a multicultural environment. *Desirable* qualifications and experience: a post-graduate degree in an appropriate technical discipline; sound knowledge of related air navigation activities within other international organizations; ability to organize, manage and advise air navigation meetings; ability to work under considerable pressure; ability to use personal computers and contemporary software.

Command of English and French is essential, with a working knowledge of Russian or Spanish is desirable.

This level carries a starting net base salary per annum of U.S. $48,019 (without dependents) and U.S. $51,597 (with dependents). Post adjustment on initial salary step is U.S. $20,167 (without dependents) and U.S. $21,670 (with dependents) per annum and is subject to change.

Initial appointment will be on a three-year, fixed-term basis (for an